Weed Science, 51:683–689. 2003

Influence of environmental factors on broadleaf signalgrass (*Brachiaria platyphylla*) germination

Ian C. Burke
Walter E. Thomas
Janet F. Spears
Crop Science Department, P.O. Box 7620, North Carolina State University, Raleigh, NC 27695-7620

John W. Wilcut
Corresponding author. Crop Science Department, P.O. Box 7620, North Carolina State University, Raleigh, NC 27695-7620; john_wilcut@ncsu.edu

Laboratory and greenhouse studies were conducted to determine the effect of temperature, solution pH, water stress, and planting depth on broadleaf signalgrass germination. Broadleaf signalgrass seed required removal of the husk for germination. When treated with constant temperature, broadleaf signalgrass germinated over a range of 20 to 35 C, with optimum germination occurring at 30 and 35 C. Onset, rate, and total germination (87%) was greatest in an alternating 20/30 C temperature regime. Germination decreased as solution pH increased, with greatest germination occurring at pH values of 4 and 5. Germination decreased with increasing water potential, and no germination occurred below − 0.8 mPa. Emergence was above 42% when seed were placed on the soil surface or buried 0.5 cm deep. Germination decreased with burial depth, but 10% of broadleaf signalgrass seed emerged from 6.0-cm depth. No seed emerged from 10-cm depth. These data suggest that broadleaf signalgrass may emerge later in the season, after rains, and could germinate rapidly and in high numbers. These attributes could contribute to poor control later in the season by soil-applied herbicides or allow broadleaf signalgrass to emerge after final postemergence treatments were made.

Nomenclature: Broadleaf signalgrass, *Brachiaria platyphylla* (Griseb.) Nash BRAPP.

Key words: Scarification, solution pH, water stress.

Studies of germination requirements yield basic ecological information for soil emergence of many weed species (Bhowmik 1997). Such information can be used to characterize the competitiveness and the potential infestation range of the weed as well as enhance management practices, allowing biological, chemical, or mechanical control options to be properly timed (Bhowmik 1997; Dyer 1995; Potter et al. 1984; Wilson 1988). Broadleaf signalgrass is a serious weed in the southeastern United States (Dowler 1998), where it is widespread and tolerant to some commonly used herbicides (Chamblee et al. 1982a; Gallaher et al. 1999). Yet despite its importance, very little information could be found or is apparently known of its germination and seedling establishment requirements.

Broadleaf signalgrass has been listed among the top 10 common and troublesome weeds in corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), and soybean [*Glycine max* (L.) Merr.] in Alabama, Florida, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas (Dowler 1998; Webster 2000). Less than four broadleaf signalgrass plants 10 m^{-1} row were predicted to reduce peanut yield (Chamblee et al. 1982b). McGregor et al. (1988) observed that each broadleaf signalgrass plant per square meter reduced rough rice (*Oryza sativa* L.) yield 18 kg ha^{-1}.

Broadleaf signalgrass, a native summer annual grass of North America, has reclining 30- to 60-cm-long stems that root at the lower nodes. The leaf blades are flat and thick, ranging from 5 to 10 mm in width and 3 to 10 cm in length (Radford et al. 1973). The inflorescence is a small panicle (hence, *Brachiaria*, Latin *brachium* for arm) with two to six short racemes, each 4 to 8 cm long with winged rachis. Spikelets are in two rows on one side of the winged axis. Seed are generally 3 mm long and finely roughened (Hitchcock and Agnes 1971; Radford et al. 1973). Flowering of broadleaf signalgrass occurs from June to October (Hitchcock and Agnes 1971; Lorenzi and Jeffery 1987; Radford et al. 1973).

The emergence of broadleaf signalgrass as a serious weed competitor was primarily due to tolerance of widely used herbicides in the late 1970s and 1980s, especially alachlor in peanut and, later, primisulfuron in corn (Chamblee et al. 1982a; Gallaher et al. 1999), allowing it to escape herbicide treatments. It competes with a wide variety of successful weedy grasses—johnsongrass [*Sorghum halepense* (L.) Pers.] in corn (Johnson and Coble 1986), fall panicum [*Panicum dichotomiflorum* (L.) Michx.] and large crabgrass [*Digitaria sanguinalis* (L.) Scop.] in cotton, peanut, and soybean (Johnson and Coble 1986). A change in species composition has been recorded in these crops under standard herbicide regimes, with broadleaf signalgrass becoming more prevalent (Johnson and Coble 1986).

Taylorson and Brown (1977) examined the effects of accelerated after-ripening for overcoming the seed dormancy of broadleaf signalgrass and found that accelerated after-ripening or light exposure treatments had no effect on broadleaf signalgrass germination. No other seed germination or growth requirement studies have been reported on broadleaf signalgrass.

Therefore, research was initiated to gain an understanding of the germination requirements of this problematic annual grass. The objectives of this research were to determine broadleaf signalgrass germination response to (1) temperature, (2) pH, (3) water stress, and (4) planting depth.

Materials and Methods

Broadleaf signalgrass seed was harvested from fallow fields near Rocky Mount, NC, on August 13, 2000. Fields from

which the seed were harvested had previously been in a peanut–cotton–corn rotation and were fallow for a single season. Seed moisture at harvest ranged from 28 to 32% by weight. The seed were allowed to dry to 9% moisture by weight and stored at room temperature until their use in experiments. Experiments were initiated 1 mo after seed harvest. The seed were sieved to remove any extraneous plant or floral material. The sieved seed were divided in an air column separator[1] and separated into light and heavy fractions. The heavy fraction, the majority of which were fully developed seed, was used in germination and emergence experiments. Seed were tested for viability using 1% tetrazolium chloride solution before each study (Peters 2000). The light fraction, the majority of which were immature seed or flowers, was discarded.

A randomized complete block design was used for experiments in seed germination chambers. Experiments performed on the gradient table precluded randomization because the zones of temperature were fixed in position (Larson 1971). There were six flasks per temperature zone on the gradient table, and each flask was one replication. Studies in seed germination chambers[2] had four replications of treatments, each of which was arranged on a different shelf within the respective seed germination chamber.

Preliminary experiments in growth chambers indicated that broadleaf signalgrass germinated independent of light. Therefore, light was provided for 8 h to coincide with the length of the high-temperature component of the temperature regime for all studies conducted in growth chambers. Observations were made during the 8-h light period.

Effect of Temperature

The effect of constant temperature was evaluated by evenly spacing 20 broadleaf signalgrass seeds in 50-ml erlenmeyer flasks containing three pieces of filter paper[3] and 8 ml of deionized water. The flasks were arranged on a gradient table (Larson 1971) in six lanes corresponding to a constant temperature of 15, 20, 25, 30, 35, and 40 C, with six flasks per lane. Flasks were sealed, using parafilm, to hold in moisture. Light was provided by fluorescent overhead bulbs set for a light–dark regime of 8:16 h. Daily germination counts were made for the first 7 d and then every 3 d until no seed germination was observed for 7 continuous days. Each seedling was considered to have germinated when a visible radicle could be discerned, and the seed was then removed from the petri dish (Baskin C. C. and Baskin J. M. 1998). The study was conducted twice and the data combined for analysis.

A separate study was conducted in growth chambers to determine broadleaf signalgrass response to diurnal temperature. Fifty broadleaf signalgrass seed were spaced evenly in 110-mm-diam by 20-mm petri dishes containing two pieces of germination paper[4] and 10 ml of deionized water. Four temperature regimes were selected to reflect typical seasonal variation in the southeastern United States, the major occurrence area of this weed. The regimes, 10/25, 15/30, 20/30, and 20/35 C, correspond to mean daily low and high temperatures for the months of May, June, July, and August, respectively, in Goldsboro, NC (Owenby and Ezell 1992). These regimes also correspond to a range of effective day and night temperatures for June, July, and August for diverse locations throughout the United States (Patterson 1990). The high-temperature component of the regime was maintained for 8 h. Daily germination counts were made until no seed germination was observed for 7 continuous days. Each seedling was removed upon germination as mentioned previously. The study was conducted twice and the data combined for analysis.

Effect of Solution pH

A study with a randomized complete block design and four replications of treatments was used to examine the effects of pH on broadleaf signalgrass germination. Buffered pH solutions were prepared according to the method described by Gortner (1949), using potassium hydrogen pthalate in combination with either 0.1 M HCl or 0.1 M NaOH to obtain pH levels of 4, 5, and 6. A 25 mM potassium hydrogen pthalate solution was used in combination with 0.1 M HCl or 0.1 M NaOH to prepare solutions with pH levels of 7, 8, or 9. Sets of 25 broadleaf signalgrass seed were placed in petri dishes containing 10 ml of the appropriate pH solution, and the petri dishes were placed in 10/25, 15/30, 20/30, and 20/35 C germination chambers. Germination was determined as previously mentioned. The study was conducted twice and the data combined for analysis.

Effect of Water Stress

A study with a randomized complete block design and four replications of treatments was used to examine the effects of water stress on broadleaf signalgrass germination. Solutions with water potentials of 0.0, − 0.3, − 0.4, − 0.6, − 0.9, and − 1.2 mPa were prepared by dissolving 0, 154, 191, 230, 297, and 350 g of polyethylene glycol[5] (PEG) in 1 L of deionized water (Michel 1983). Twenty-five broadleaf signalgrass seed were placed in petri dishes containing 10 ml of PEG solution, and the petri dishes were placed in 10/25, 15/30, 20/30, and 20/35 C germination chambers. Germination was determined as mentioned previously. The study was conducted twice and the data combined for analysis.

Depth of Emergence

A depth of emergence study was conducted in a glasshouse at an average daily temperature of 33 ± 5 C and a nightly temperature of 23 ± 5 C. Natural light supplemented with fluorescent lamps at a light intensity of 300 ± 20 μmol m^{-2} s^{-1} was used to extend light duration to 14 h in glasshouse studies and to simulate field conditions. The depth of emergence study included four replications of treatments in a randomized complete block design. The study was conducted three times and the data combined for analysis.

Depths of 0.5, 1.0, 2.0, 4.0, 6.0, and 10.0 cm were marked inside 1,400-ml pots. The pots were then filled to that mark with sterilized Norfolk sandy loam soil (fine-loamy, siliceous, thermic Typic Kandiudults, pH 5.1, cation exchange capacity 2.0), sifted with a #30[6] sieve. Using sieved soil facilitated the recovery of any nongerminated seed. Pots were agitated to achieve a consistent bulk density of 0.92 g cm^{-3}. Twenty broadleaf signalgrass seed were placed on the soil surface or covered with the same soil to the depths listed above. Each pot contained 1,200 cm^3 of soil. Pots were

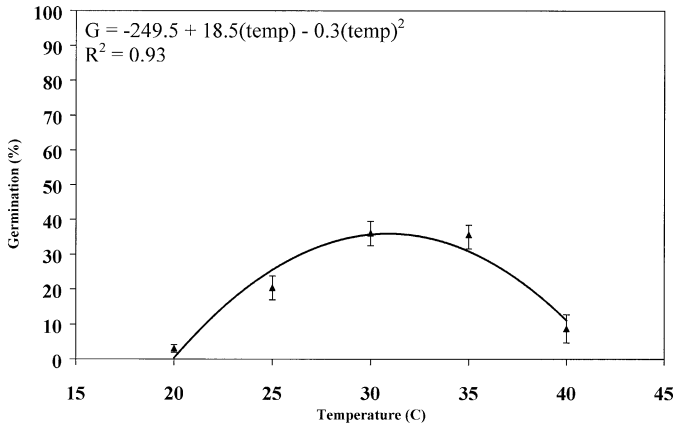


FIGURE 1. Influence of constant temperature on cumulative germination of broadleaf signalgrass at 14 d as described by equation $y = \beta_0 + \beta_1 \text{temp} + \beta_2 \text{temp}^2$. Error bars indicate standard error of the mean.

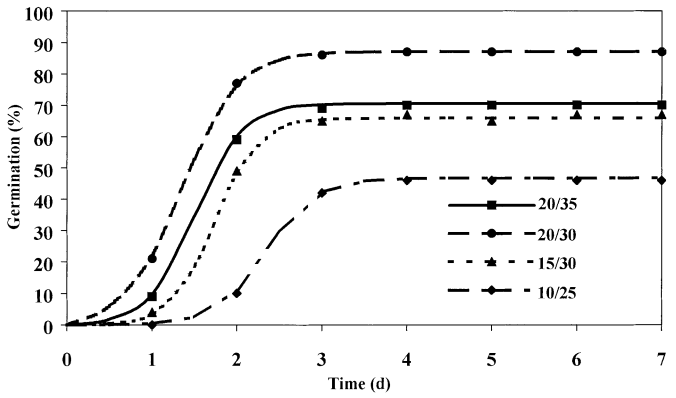


FIGURE 2. Influence of four temperature regimes on broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] germination, modeled using the equation $y = M[1 + \exp(-K(t - L))]^{-1}$ with estimated parameters (and standard errors).

Temperature	*M*	*K*	*L*	R^2
10/25	87.1 (0.2)	3.02 (0.11)	1.45 (0.01)	0.99
15/30	70.6 (0.3)	3.60 (0.13)	1.51 (0.02)	0.99
20/30	65.9 (0.3)	3.89 (0.20)	1.74 (0.01)	0.99
20/35	46.7 (0.5)	3.43 (0.32)	2.34 (0.03)	0.99

subirrigated initially to field capacity and then surface irrigated three times daily using an overhead sprinkler system. Emergence counts were recorded daily for the first 7 d and then every 3 d until no seed germination or emergence was observed for 7 continuous days. Plants were considered to have emerged when a cotyledon could be visibly discerned. The soil was placed in a root washer on a #30 sieve and the soil removed to recover and quantify any nongerminated seed.

Statistical Analysis

Data variance was visually inspected by plotting residuals to confirm homogeneity of variance before statistical analysis. Both nontransformed and arcsine-transformed data were examined, and transformation did not improve homogeneity. Analysis of variance (ANOVA) was therefore performed on nontransformed percent germination. Trial repetition and linear, quadratic, and higher-order polynomial effects of percent germination over time were tested by partitioning sums of squares (Draper and Smith 1981). Regression analysis was performed when indicated by ANOVA. Nonlinear models were used if ANOVA indicated that higher-order polynomial effects of percent germination were more significant than linear or quadratic estimates. Estimation used the Gauss–Newton algorithm, a nonlinear least squares technique (SAS 1998).

Germination resulting from constant temperature was described by a parabolic model of the form

$$y = \beta_0 + \beta_1 \text{temp} + \beta_2 \text{temp}^2 \quad [1]$$

where β_0, β_1, and β_2 are the intercept, first-order and second-order regression coefficients, respectively, and y is the cumulative germination at temperature temp.

Analysis of variance indicated higher-order polynomial effects for germination resulting from alternating temperature treatments, solution pH treatments, and water potential treatments. Therefore, germination resulting from alternating temperatures was modeled using the logistic function

$$y = M[1 + \exp(-K(t - L))]^{-1} \quad [2]$$

where y is the cumulative percent germination at time t, M is the asymptote or theoretical maximum for y, L is the time-scale constant or lag to onset of germination, and K is the rate of increase (Roché et al. 1997). When a nonlinear equation was fit to the data, an approximate R^2 value was obtained by subtracting the ratio of the residual sums of squares to the corrected total sums of squares from one (Draper and Smith 1981).

Depth of emergence data were subjected to an ANOVA using the general linear models procedure provided with SAS (1998). No broadleaf signalgrass plants emerged from 10 cm, and, consequently, these data were not included in the analysis. Sums of squares were partitioned to evaluate planting depth and trial repetition. Both experiment replication and trials were considered random variables, and main effects and interactions were tested by the appropriate mean square associated with the random variable (McIntosh 1983). Mean separations were performed using Fisher's Protected LSD test at $P = 0.05$.

Results and Discussion

Broadleaf signalgrass seed tested 92% viable by tetrazoleum chloride tests (Peters 2000) before each study was conducted (data not shown). The seed exhibited innate dormancy, and initial experiments on seed with the husk in place resulted in maximum germination of 9% (data not shown). Dormancy in the genus *Brachiaria* is typically overcome by removing the husk, which is made up of the overlapping lemma and palea of the fertile floret (Hopkinson et al. 1996; Renard and Capelle 1976; Whiteman and Mendra 1982). Removal of the husk resulted in increased germination, and this procedure was used in all subsequent experiments. Others have noted numerically lower densities of broadleaf signalgrass in crop rotations that included no-till or strip-till production practices (Mueller and Hayes 1997), which suggests that broadleaf signalgrass seed may require mechanical action to break or remove the husk for germination to occur in the field.

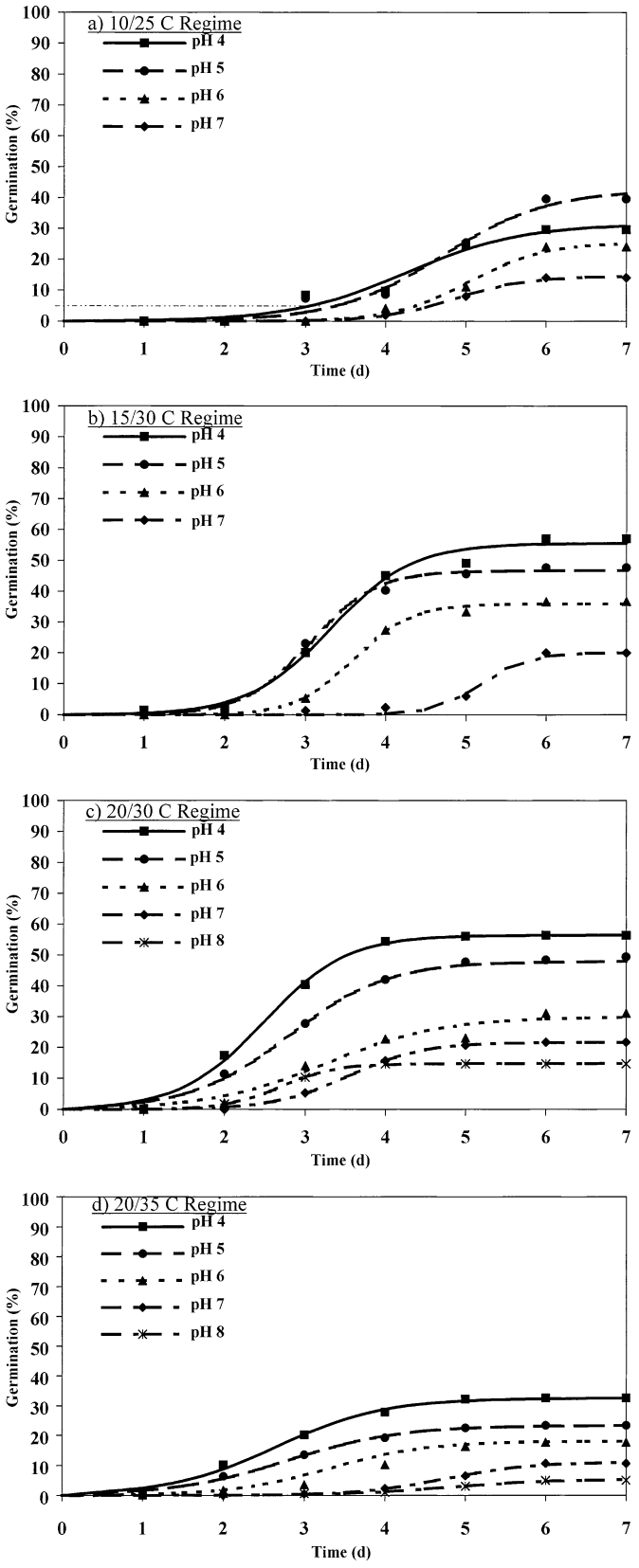


FIGURE 3. Influence of solution pH on broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] germination under (a) 10/25 C, (b) 15/30, (c) 20/30, and (d) 20/35 C temperature regimes, using the equation $y = M[1 + \exp(-K(t - L))]^{-1}$ with estimated parameters (and standard errors).

Temperature

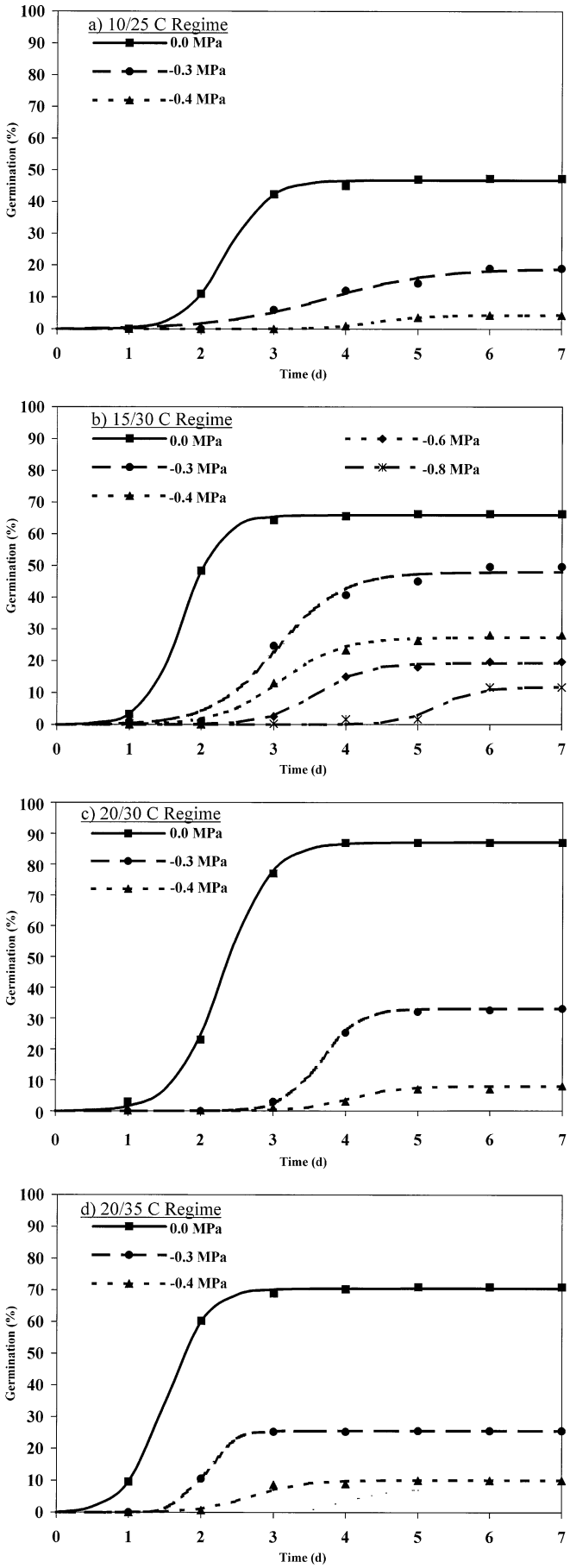
When exposed to constant temperature, broadleaf signalgrass seed germinated over a temperature range of 20 to 35 C (Figure 1). Broadleaf signalgrass seed did not germinate when kept at a constant temperature of 15 C. Constant temperature resulted in a maximum germination of 35% at 30 and 35 C.

Onset, rate, and maximum germination varied with alternating temperature regimes (Figure 2), and ANOVA indicated a significant temperature regime by germination interaction, so broadleaf signalgrass germination is presented for each temperature regime. Maximum cumulative germination (87%) of broadleaf signalgrass occurred when seed were exposed to 20/30 C. The germination rate (parameter *K*) produced by the 20/30 C regime was lower than the rates at the 15/30 and 20/35 C regimes. However, these differences are most likely related to differences in final germination percentages. If one considers how many seed germinated in the first 48 h, there were more seedlings started at 20/30 C than at any other temperature regime. The time to 50% cumulative seed germination was fastest in the 20/30 C regime at 1.4 d and could be caused by the 10° difference in the temperature components of the 20/30 C regime. Time to 50% germination in the 15/30 and 20/35 C regimes were 1.7 and 1.5 d, respectively, and both regimes had a 15 degree difference between their respective temperature components. Total percent germination was lowest in the 10/25 C regime. The lower cumulative germination at low temperature could indicate that broadleaf signalgrass germinates later in the warmer part of the growing season, which includes the months of June, July, and August.

It is interesting to note that when the seed used in this experiment were germinated at constant temperature, they germinated equally well at both 30 and 35 C (Figure 1). However, there was a substantial difference in maximum germination when seed were exposed to alternating temperatures of 20/30 or 20/35 C (Figure 2). The preference for alternating temperatures, therefore, could be associated with the spread between maximum and minimum temperatures,

←

Temperature	pH	*M*	*K*	*L*	R^2
10/25	4	31.5 (3.0)	1.39 (0.43)	4.27 (0.27)	0.98
	5	42.6 (3.6)	1.53 (0.37)	4.72 (0.21)	0.98
	6	25.3 (1.5)	2.13 (0.49)	5.04 (0.12)	0.99
	7	14.5 (0.4)	2.31 (0.25)	4.88 (0.05)	0.99
15/30	4	55.6 (1.8)	1.97 (0.28)	3.31 (0.09)	0.99
	5	46.7 (1.2)	2.47 (0.48)	3.06 (0.07)	0.99
	6	35.9 (0.7)	2.81 (0.28)	3.61 (0.05)	0.99
	7	19.9 (1.6)	3.50 (0.36)	5.22 (0.11)	0.97
20/30	4	56.4 (1.0)	1.96 (0.20)	2.48 (0.06)	0.99
	5	48.9 (0.9)	1.61 (0.16)	2.83 (0.07)	0.99
	6	29.8 (2.3)	1.40 (0.43)	3.27 (0.26)	0.99
	7	21.7 (0.3)	2.16 (0.13)	3.54 (0.04)	0.99
	8	14.7 (0.1)	2.96 (0.11)	2.71 (0.02)	0.99
20/35	4	32.6 (1.0)	1.51 (0.22)	2.66 (0.11)	0.98
	5	23.3 (0.7)	1.45 (0.18)	2.80 (0.10)	0.99
	6	18.1 (0.4)	1.66 (0.16)	3.82 (0.07)	0.99
	7	11.2 (0.4)	1.86 (0.22)	4.77 (0.08)	0.99
	8	5.4 (0.5)	1.54 (0.40)	4.81 (0.24)	0.97



10 vs. 15 C for 20/30 and 20/35 C, respectively, rather than the absolute maximum and minimum temperature (Baskin C. C. and Baskin J. M. 1998; Thompson and Grime 1983).

Response to Solution pH

Analysis of variance indicated a significant temperature regime by pH interaction, so broadleaf signalgrass seed germination is presented for each pH within each temperature regime. The 20/30 C regime produced the greatest amount of cumulative germination at each pH level (Figure 3c). No germination of seed was observed at pH of 8 or 9 in the 10/25 and 15/30 C temperature regimes (Figures 3a and 3b) or at pH of 9 in the 20/30 or 20/35 C regimes (Figures 3c and 3d). The order of cumulative germination for each pH, from highest to lowest, was similar in the 15/30, 20/30, and 20/35 C temperature regimes (Figures 3b–d). In the 10/25 C regime, more broadleaf signalgrass seed germinated at pH 5 than at pH 4 (Figure 3a). Cumulative broadleaf signalgrass seed germination was greater and time to 50% germination lower at pH 4 and 5 than at all other pH values in all temperature regimes. Maximum cumulative germination decreased as pH increased, indicating that broadleaf signalgrass germination is sensitive to changes in pH. These data suggest that broadleaf signalgrass prefers acidic soil conditions, which are common throughout the major crop production regions of the North Carolina Piedmont and Coastal Plain (Tucker et al. 1997). Adaptation to low-fertility acid soils is typical of the genus *Brachiaria*, which has its center of diversity in Africa (Parsons 1972; Rao et al. 1996).

Response to Water Stress

Analysis of variance indicated a significant temperature regime by water stress treatment interaction, so broadleaf signalgrass germination is presented for each water stress

←

FIGURE 4. Influence of water stress (ψ) on broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] germination under (a) 10/25 C, (b) 15/30, (c) 20/30, and (d) 20/35 C temperature regimes, using the equation $y = M[1 + \exp(-K(t - L))]^{-1}$ with estimated parameters (and standard errors).

Temperature	ψ (mPa)	*M*	*K*	*L*	R^2
10/25	0.0	46.7 (0.5)	3.43 (0.27)	2.34 (0.03)	0.99
	− 0.3	19.0 (1.3)	1.35 (0.32)	3.73 (0.22)	0.99
	− 0.4	4.4 (0.03)	2.92 (0.09)	4.42 (0.02)	0.97
15/30	0.0	65.9 (0.3)	3.89 (0.21)	1.74 (0.10)	0.99
	− 0.3	47.9 (1.7)	2.22 (0.49)	3.05 (0.08)	0.99
	− 0.4	27.3 (0.8)	2.39 (0.47)	3.10 (0.05)	0.97
	− 0.6	19.6 (0.4)	3.01 (0.31)	3.59 (0.05)	0.97
	− 0.8	11.7 (0.9)	3.80 (0.67)	5.29 (0.12)	0.96
20/30	0.0	87.1 (0.4)	3.07 (0.11)	2.36 (0.02)	0.99
	− 0.3	33.0 (0.3)	3.85 (0.23)	3.72 (0.03)	0.99
	− 0.4	7.9 (0.1)	3.15 (0.46)	4.05 (0.03)	0.99
20/35	0.0	70.6 (0.3)	3.60 (0.13)	1.51 (0.02)	0.99
	− 0.3	25.6 (0.1)	5.22 (0.79)	2.06 (0.01)	0.99
	− 0.4	10.1 (0.2)	2.97 (0.61)	2.71 (0.04)	0.98

TABLE 1. Cumulative emergence of broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] seed buried at 0, 0.5, 1, 2, 4, and 6 cm 7 and 14 d after planting (DAP).[a]

Burial depth	Emergence	
	7 DAP	14 DAP
cm	%	
0.0	11	43
0.5	4	48
1.0	9	39
2.0	0	28
4.0	0	24
6.0	0	10
LSD (0.05)	6	17

[a] Average day and night temperatures were 33 ± 5 C and 23 ± 5 C, respectively.

treatment within each temperature regime. As water stress increased, cumulative broadleaf signalgrass seed germination decreased (Figures 4a–d). No germination occurred when the water potential was − 1.2, regardless of the germination temperature (data not shown). Broadleaf signalgrass seed germinated at a water potential of − 0.8 mPa only in the 15/30 C regime (Figure 4b). When the water potential was 0.0 (seed in deionized water), maximum germination (87%) occurred in the 20/30 C temperature regime (Figure 4c). Placing seed in water stress delayed the onset of germination in all temperature regimes, causing the time to 50% germination (*L*) to increase for − 0.3 and − 0.4 mPa compared with 0.0 mPa (Figures 4a–d). Although imbibition is a complicated process, most likely the osmotic gradient was overcome by a greater concentration of solutes within the seed than without, and, consequently, water was able to move into the seed (Baskin C. C. and Baskin J. M. 1998). The requirement for low water stress also suggests that broadleaf signalgrass is dependent upon irrigation or rain for germination in the field.

Depth of Emergence

Emergence of broadleaf signalgrass decreased with increased planting depth, with the numerical maximum of 48% occurring 14 d after planting from the 0.5-cm depth (Table 1). There was no difference in germination of seed planted on the surface at a depth of 0.5 or 1.0 cm. No viable seed were recovered from the soil after 14 d, which is likely explained by the absence of a husk to protect seed that did not germinate. Emergence after burial in soil depends, in part, on seed size. Larger seed with greater carbohydrate reserves can emerge from greater depths of burial (Baskin C. C. and Baskin J. M. 1998). Broadleaf signalgrass possesses a similar seed size, 3-mm length, compared with other grasses such as giant foxtail (*Setaria faberi* Herrm.) (2 to 2.5 mm long) or fall panicum (2 to 2.5 mm long) (Hitchcock and Agnes 1971; Radford et al. 1973). Broadleaf signalgrass percent emergence was similar to fall panicum and giant foxtail at depths of 0 and 1.0 cm and less than either at depths greater than 1.0 cm (Fausey and Renner 1997). Both fall panicum and giant foxtail germinated from 7.5 cm depth (Fausey and Renner 1997). Broadleaf signalgrass germinated from a depth of 6 cm, but no germination was observed from a depth of 10 cm (Table 1). Emergence from depths of up to 6 cm could allow broadleaf signalgrass to escape control from soil-applied herbicides.

Broadleaf signalgrass seed did not tolerate water stress and required warm alternating temperatures, burial depths of 2.0 cm or less, and an acidic solution pH for maximum germination. These data suggest that broadleaf signalgrass may emerge throughout the season from mid-May through mid-September and germination is likely triggered by rains. Furthermore, if conditions are right, broadleaf signalgrass will germinate rapidly and in high numbers. These attributes could contribute to poor control later in the season by soil-applied herbicides after they have degraded in the soil. Additionally, high weed densities have been shown to decrease herbicide efficacy (Doub et al. 1988; Hartzler and Roth 1993). Emergence after final postemergence herbicide applications or from greater depths also could contribute to a lack of season-long control in many weed management programs (Chamblee et al. 1982a; Mueller and Hayes 1997).

Because the seed require scarification for germination, soil disturbance in conventional tillage systems could increase broadleaf signalgrass emergence and therefore deplete the seedbank. Other grass weeds with similar attributes (rapid high germination), such as woolly cupgrass [*Eriochloa villosa* (Thunb.) Kunth] and giant foxtail, have been shown to decline rapidly from the seedbank (Buhler and Hartzler 2001). A weed control system that took advantage of the seed depletion and controlled late-season weed escapes might deplete the soil of broadleaf signalgrass seed in several seasons. Use of a no-tillage cropping system also could reduce broadleaf signalgrass germination. These attributes, coupled with the reported tolerance to commonly used herbicides, such as alachlor, pendimethalin, and primisulfuron, in corn, cotton, and peanut (Chamblee et al. 1982a; Gallaher et al. 1999; Mueller and Hayes 1997), should be taken into account when managing for broadleaf signalgrass.

Sources of Materials

[1] Seed blower, Seedburo Equipment Company, 1022 West Jackson Boulevard, Chicago, IL 60607.

[2] SG8S germination chamber, Hoffman Manufacturing Inc., International Agri-Supply, 353 29th Avenue SW, Albany, OR 97321.

[3] Watman #3 filter paper, Fisher Scientific, P.O. Box 4829, Norcross, GA 30091.

[4] 9.0 cm germination paper, Anchor Paper Company, 480 Broadway, St. Paul, MN 55165-0648.

[5] PEG 8000, Sigma Chemicals, P.O. Box 14508, St. Louis, MO 63178.

[6] #30 sieve, The W. S. Tyler Company, 8750 Tyler Boulevard, Mentor 14, OH 44060.

Acknowledgments

The authors thank Dr. Shawn Askew for advice and Dr. Cavell Brownie, Department of Statistics, North Carolina State University, for expert statistical assistance; appreciation also is extended to Brenda Penny, Scott Clewis, Andy Price, and Shawn Troxler for technical assistance.

Literature Cited

Baskin, C. C. and J. M. Baskin. 1998. Seeds: Ecology, Biogeography and Evolution of Dormancy and Germination. New York: Academic Press. pp. 12–13, 212.

Bhowmik, P. C. 1997. Weed biology: importance to weed management. Weed Sci. 45:349–356.
Buhler, D. D. and R. G. Hartzler. 2001. Emergence and persistence of seed of velvetleaf, common waterhemp, woolly cupgrass, and giant foxtail. Weed Sci. 49:230–235.
Chamblee, R. W., L. Thompson, Jr., and T. M. Bunn. 1982a. Management of broadleaf signalgrass (*Brachiaria platyphylla*) in peanuts (*Arachis hypogaea*) with herbicides. Weed Sci. 30:40–44.
Chamblee, R. W., L. Thompson, Jr., and H. D. Coble. 1982b. Interference of broadleaf signalgrass (*Brachiaria platyphylla*) in peanuts (*Arachis hypogaea*). Weed Sci. 30:45–49.
Doub, J. P., H. P. Wilson, T. E. Hines, and K. K. Hatzios. 1988. Consecutive annual applications of alachlor and metolachlor to continuous no-till corn (*Zea mays*). Weed Sci. 36:340–344.
Dowler, C. C. 1998. Weed survey—southern states. Proc. South. Weed Sci. Soc. 51:299–313.
Draper, N. R. and H. Smith. 1981. Applied Regression Analysis. New York: J. Wiley. pp. 33–42, 511.
Dyer, W. E. 1995. Exploiting weed seed dormancy and germination requirements through agronomic practices. Weed Sci. 43:498–503.
Fausey, J. C. and K. A. Renner. 1997. Germination, emergence, and growth of giant foxtail (*Setaria faberi*) and fall panicum (*Panicum dichotomiflorum*). Weed Sci. 45:423–425.
Gallaher, K., T. C. Mueller, R. M. Hayes, O. Schwartz, and M. Barrett. 1999. Absorption, translocation, and metabolism of primisulfuron and nicosulfuron in broadleaf signalgrass (*Brachiaria platyphylla*) and corn. Weed Sci. 47:8–12.
Gortner, R. A., Jr. 1949. Outlines of Biochemistry. 3rd ed. New York: J. Wiley. pp. 82–87.
Hartzler, R. G. and G. W. Roth. 1993. Effect of prior year's weed control on herbicide effectiveness in corn (*Zea mays*). Weed Technol. 7:611–614.
Hitchcock, A. S. and C. Agnes. 1971. Manual of the Grasses of the United States. New York: Dover Publications. pp. 593–594.
Hopkinson, J. M., F.H.D. de Souza, S. Diulgheroff, A. Ortiz, and M. Sánchez. 1996. Reproductive physiology, seed production, and seed quality of *Brachiaria*. Pages 124–140 *in* J. W. Miles, B. L. Maass, and C. B. do Valle, eds. *Brachiaria*: Biology, Agronomy, and Improvement. Cali, Colombia: International Center for Tropical Agriculture.
Johnson, W. C. and H. D. Coble. 1986. Crop rotation and herbicide effects on the population dynamics of two annual grasses. Weed Sci. 34:452–456.
Larson, A. L. 1971. Two-Way Thermogradient Plate for Seed Germination Research: Construction Plans and Procedures. USDA—ARS 51-41.
Lorenzi, H. and L. S. Jeffery. 1987. Weeds of the United States and Their Control. New York: Von Nostrand Reinhold. 54 p.
McGregor, J. T., Jr., R. J. Smith, Jr., and R. E. Talbert. 1988. Interspecific and intraspecific interference of broadleaf signalgrass (*Brachiaria platyphylla*) in rice (*Oryza sativa*). Weed Sci. 36:589–593.
McIntosh, M. S. 1983. Analysis of combined experiments. Agron. J. 75: 153–155.
Michel, B. E. 1983. Evaluation of the water potentials of solutions of polyethylene glycol 8000 both in the absence and presence of other solutes. Plant Physiol. 72:66–70.
Mueller, T. C. and R. M. Hayes. 1997. Effect of tillage and soil-applied herbicides on broadleaf signalgrass (*Brachiaria platyphylla*) control in corn (*Zea mays*). Weed Technol. 11:698–703.
Owenby, J. R. and D. S. Ezell. 1992. Climatography of the United States. No. 81. Daily Normals of Temperature and Heating and Cooling Degree Days North Carolina 1961–1990. Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environment Data Services, National Climatic Center.
Parsons, J. J. 1972. Spread of African pasture grasses to the American tropics. J. Range Manag. 25:12–17.
Patterson, D. T. 1990. Effects of day and night temperature on vegetative growth of Texas panicum (*Panicum texanum*). Weed Sci. 38:365–373.
Peters, J., ed. 2000. Association of Official Seed Analysts Tetrazoleum Testing Handbook Contribution #29 1st Revision. Lincoln, NE: Association of Official Seed Analysts. pp. 19–21.
Potter, R. L., J. L. Peterson, and D. N. Ueckert. 1984. Germination responses of *Opuntia* spp. to temperature, scarification, and other seed treatments. Weed Sci. 32:106–110.
Radford, A. E., H. E. Ahles, and C. R. Bell. 1973. Manual of the Vascular Flora of the Carolinas. Chapel Hill, NC: The University of North Carolina Press. 139 p.
Rao, I. M., P. C. Kerridge, and M.C.M. Macedo. 1996. Nutritional requirements of *Brachiaria* and adaptation to acid soils. Pages 53–71 *in* J. W. Miles, B. L. Maass, and C. B. do Valle, eds. *Brachiaria*: Biology, Agronomy, and Improvement. Cali, Colombia: International Center for Tropical Agriculture.
Renard, C. and P. Capelle. 1976. Seed germination in ruzizi grass (*Brachiaria ruziziensis* Germain et Evrard). Aust. J. Bot. 24:437–446.
Roché, C. T., D. C. Thill, and B. Shafii. 1997. Estimation of base and optimum temperatures for seed germination in common crupina (*Crupina vulgaris*). Weed Sci. 45:539–533.
[SAS] Statistical Analysis Systems. 1998. SAS/STAT User's Guide. Release 7.00. Cary, NC: Statistical Analysis Systems Institute. 1028 p.
Taylorson, R. B. and M. M. Brown. 1977. Accelerated after-ripening for overcoming seed dormancy in grass weeds. Weed Sci. 25:473–477.
Thompson, K. and J. P. Grime. 1983. A comparative study of germination responses to diurnally fluctuating temperatures. J. Appl. Ecol. 20:141–156.
Tucker, M. R., J. K. Messick, and C. C. Carter. 1997. Crop Fertilization Based on North Carolina Soil Tests. Raleigh, NC: North Carolina Department of Agriculture, Agronomic Division. 81 p. [Agronomic Division Circular No. 1, revised.]
Webster, T. M. 2000. Weed survey—southern states. Proc. South. Weed Sci. Soc. 53:247–274.
Whiteman, P. C. and K. Mendra. 1982. Effects of storage and seed treatments on germination of *Brachiaria decumbens*. Seed Sci. Technol. 10: 233–242.
Wilson, R. G. 1988. Biology of weed seeds in the soil. Pages 25–39 *in* M. A. Altieri and M. Liebman, eds. Weed Management in Agroecosystems: Ecological Approaches. Boca Raton, FL: CRC Press.

Received February 5, 2002, and approved January 21, 2003.